Pergamon

LATE-GLACIAL POLLEN, MACROFOSSILS AND FISH REMAINS IN NORTHEASTERN U.S.A. — THE YOUNGER DRYAS OSCILLATION

A Contribution to the 'North Atlantic Seaboard Programme' of IGCP-253, 'Termination of the Pleistocene'

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The late-glacial environmental histories of Allamuchy Pond, New Jersey and Linsley Pond, Connecticut are reconstructed from pollen, macrofossil and fish scale remains. Accelerator mass spectrometry (AMS) ^{14}C dating of seeds and needles indicates that the first organic deposition, evidenced by fossil *Picea* (spruce) needles, occurred approximately 12,400 BP. A major regional warming began in the northeastern United States at this time, correlative with the Bølling/Allerød warming of Europe and Greenland. The increase in *Quercus* (oak) pollen and presence of *Pinus strobus* (white pine) needles demonstrates the magnitude of warming reached at about 11,000 BP. The subsequent decline of thermophilous species and increase in boreal *Picea, Abies* (fir), *Larix* (larch), *Betula papyrifera* (paper birch) and *Alnus* (alder) from 10,800–10,000 BP was a regional vegetational reversal. Thus we find a North American expression of the Younger Dryas with a mean annual temperature depression of 3–4° C. The subsequent classical southern New England pine pollen zone 'B' and *Pinus strobus* macrofossils signalled a return to warmer conditions at approximately 10,000 BP, regionally, within approximately 50–100 years. A large increase in *Quercus* follows. This study is unique in documenting a continuous late-glacial record of fish remains from Allamuchy Pond, New Jersey sediments, indicating that members of the families Centrarchidae (sunfish), Salmonidae (trout), Percidae (perch) and Cyprinidae (minnow) were regionally present.

INTRODUCTION

The recent refinement of the late-glacial Greenland ice core stratigraphy (Johnsen *et al.*, 1992; Taylor *et al.*, 1993; Alley *et al.*, 1993) enables improved correlation of late-glacial events throughout the North Atlantic region, ranging from Europe across the North Atlantic basin to eastern North America. The Greenland Summit ice core evidence for the onset of the Bolling interval is 14,450±250 BP, which translates to 12,500 ^{14}C years (Bard *et al.*, 1992), which is within 200 years of the GISP-2 estimate (Taylor *et al.*, 1993). The Bølling/Allerød-Younger Dryas oscillations are events clearly visible in the isotopes (Dansgaard *et al.*, 1989), snow accumulation (Alley *et al.*, 1993) and dust (Taylor *et al.*, 1993) shifts in ice cores, North Atlantic marine faunal records (Ruddiman and McIntyre, 1981; Broecker *et al.*, 1985; Lehman and Keigwin, 1992) and palynological data in Europe (Watts, 1980; Rind *et al.*, 1986) and eastern North America (Mott *et al.*, 1986; Peteet, 1987; Peteet *et al.*, 1990; Levesque *et al.*, 1993). The rapidity of the transitions, occurring within decades in Greenland, provide an exciting focus for examining various responses from the fossil record. Because of the abrupt nature of the late-glacial changes, AMS ^{14}C chronology is essential for dating and terrestrial macrofossils are the primary fossil of choice (Tornqvist, 1992). All dates are in radiocarbon years unless otherwise noted.

Several key questions concern the last glacial–interglacial transition in the northeastern U.S. This study focuses on palynology, faunal and floral macrofossils and AMS radiocarbon chronology from three sites that present a regional picture. Linsley Pond, Connecticut and Allamuchy Pond, New Jersey (Fig. 1) are new sites, in addition to Alpine Swamp, New Jersey (Peteet *et al.*, 1990). A unique feature of the study is the continuous stratigraphic presence of fish remains from Allamuchy Pond, northwestern New Jersey. The following questions concern the biological response to major deglaciation in the northeastern United States:

(1) What was the timing of the first warming in southern New England and how does this compare with other North Atlantic records?

(2) What was the general pattern of warming in this region and how is it expressed in the sedimentary, paleovegetational and fish remains records?

(3) What is the timing and magnitude of the Younger Dryas cooling in the coastal northeastern U.S.?

(4) What patterns of tree migration are evident from the presence of macrofossils?

SETTING AND BACKGROUND

The climate of New Jersey and Connecticut has both continental and oceanic features. Linsley Pond, Connecticut, is situated in a maritime climate while Allamuchy Pond is about 60 km inland, in northwestern New Jersey. Mean annual temperature ranges from 7 to 10°C and is higher in coastal areas. Annual rainfall ranges from 110 to 125 cm.

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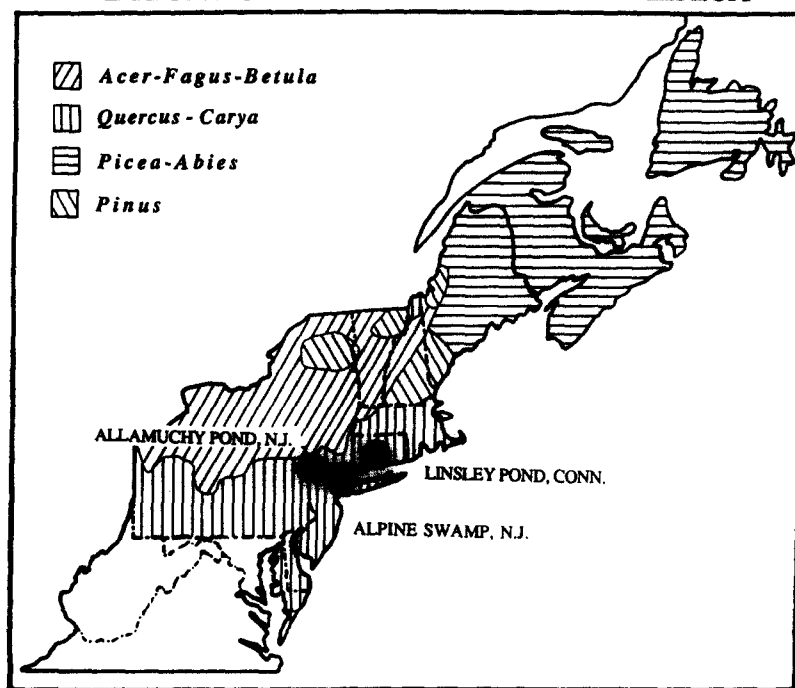
VEGETATION OF EASTERN NORTH AMERICA

FIG. 1. Map of northeastern U.S. with location of three sites discussed (circles). Modern vegetation distribution after Kuchler, (1964).

Storms from the Great Lakes region, which pass down the St Lawrence Valley, contribute some of the precipitation, but most is derived from coastal storms of subtropical origin (van der Leeden and Troise, 1968).

The vegetation of the region is a transition zone between Hemlock-White Pine-Northern Hardwoods forests to the north (Braun, 1950; Kuchler, 1964) and deciduous forests to the south (Fig. 1). It is classified as Oak-Chestnut forest (Braun, 1950), but contains *Acer saccharum* (sugar maple), *Carya* (hickory), *Fagus grandifolia* (beech), *Betula lutea* (yellow birch), *Pinus strobus* and *Tsuga canadensis* (hemlock). The communities surrounding Linsley Pond and Allamuchy Pond have been vastly altered by human disturbance.

Geologic data concerning the timing of ice retreat from the classical Wisconsin terminal moraines in the New Jersey–Connecticut region are controversial. Estimates of retreat are as early as 17,000 BP (Borns, 1973; Connally and Sirkin, 1973; Cotter *et al.*, 1985) to much later ages (i.e. 13,000 BP) because of the numerous problems in accepting bulk dates (Lowe and Walker, 1980; Karrow *et al.*, 1984). The debate from Corry Bog, Pennsylvania focuses clearly on the argument, still unresolved, of the true age of basal sediments (Cotter *et al*, 1985; Karrow *et al.*, 1984, 1986). AMS ^{14}C dating from many sites is needed to resolve the controversy in establishing a regional pattern.

The classic 'tundra' or 'herb' zone at the base of many of the southern New England pollen diagrams suggests that early deglaciation was followed by an open tundra landscape (Gaudreau and Webb, 1985). However, pine and spruce pollen is usually present, suggesting alternatively that a park-tundra existed, with some trees adjacent to the ice margin. The presence of spruce needles at Longswamp, Pennsylvania (Watts, 1979) during the herb zone indicates

that this may have been the case. Whether or not scattered trees were regionally present as ice retreated awaits further site macrofossil investigations.

Geomorphological evidence supports the reconstruction of a periglacial climate which resulted in permafrost for several thousand years after ice retreat (Stone *et al.*, 1991). Ice-wedge casts, pingo scars, eolian deposits and cryoturbation structures have been identified in Connecticut and Massachusetts (Stone and Ashley, 1992).

The basal sediments in this study are clays and silts, from which we screened macrofossils to determine the age of first regional organic deposition. The ages of these initial terrestrial macrofossils are used to infer a regional climatic warming from 12,600 to 12,300 BP. It is possible, of course, that large-scale ice retreat was even earlier and that remnant dead ice remained in the lakes for several hundred years. AMS radiocarbon dates from the southeastern U.S. show warming as early as 17,000 BP (Kneller and Peteet, 1993).

Linsley Pond (Fig. 1) at 65 m elevation is a small kettle lake in southern Connecticut (41°18′ N, 72°45′ W) in the headwaters of the Branford River in North Branford. It is strongly eutrophic, about 10 hectares in area, 14.8 m deep and has been extensively studied, beginning with Deevey (1939) and continuing with Vallentyne and Swabey (1955). We retrieved a 12 m core in 9.2 m of water about 9 m from the southeastern shore. The core was very organic throughout to 9.4 m and composed of silty organic sediment from 9.4 to 12 m.

Allamuchy Pond (Fig. 1) lies at an elevation of 218 m in a NE–SW trending valley near the western border of northern New Jersey (40°55′ N, 74°50′ W). The lake is oblong in shape, roughly 0.5 km long by 0.4 km wide. The core was taken in 7 m of water and is composed of soft gyttja from 0 to 7.0 m, then dark brown consolidated gyttja from 7.0 to 9.0 m. From 9.0 to 9.3 m depth it is olive-brown clay with some silt.

PREVIOUS FISH REMAINS STUDIES

Few reports mention the presence of fish remains in sediment cores. Lagler and Vallentyne (1956) retrieved two scales, one identified as belonging to a killifish (family Cyprinidontidae) and the other from a minnow (family Cyprinidae) from Linsley Pond, Connecticut and dated at 7500 BP. Pennington and Frost (1961) found scales and vertebrae 450 cm below the substrate surface in a core from Esthwaite Water in the English Lake District. The remains were either a trout or charr, with a probable age of 10,000 to 12,000 BP.

Casteel et al. (1977) discovered abundant fish scales and bones in cores from Clear Lake, California. Most of the remains were from Hysterocarpus traski (tule perch) and Archoplites interruptus (Sacramento perch). The majority of the remains were taken from sediments younger than 11,000 BP, but some were older than 20,000 BP.

Vallentyne (1960) conducted a survey of four ponds in New York and Ontario in an effort to examine the frequency of preservation of fish remains in lake sediments. He found no remains in the deep-water sediments of two of the lakes, but abundant remains, primarily of Perca flavescens (yellow perch), in the upper 15 cm of the third lake. He also examined cores taken from a hatchery pond in which a known number of fish had disappeared to roughly determine the percentage of scales and bones that might be preserved. He estimated that 6% were preserved. The results indicate that few remains are likely to be preserved and that preservation depends on several environmental factors.

METHODS

Sediment cores were retrieved from both ice-covered ponds in winter using a modified Livingstone piston corer (Wright et al., 1984). The sediments were refrigerated, then sampled at 5 or 10-cm intervals for pollen and macrofossil analysis of the lower half of the cores.

Percent Organic Carbon

Several samples from each core were measured for loss-on-ignition according to Dean (1974). These samples were selected from four different pollen zones in an attempt to indicate whether or not a reversal in percent organic carbon was characteristic of the stratigraphy.

Pollen and Spores

Tablets of exotic Eucalyptus were added to the pollen samples to determine pollen concentration (Benninghoff, 1962). Samples were processed using 2–5 mL of sediment, following the procedures of Heusser and Stock (1984). These included treatment with KOH, HF and HCL, screening with 150 μm and 7 μm screens (Cwynar et al., 1979), oxidation of some samples with a sodium chlorate mixture, acetolysis and silicone oil mounts. Nomenclature follows Gray's Manual of Botany (Fernald, 1970). A minimum of 300 pollen grains per sample was counted, including very few aquatics. Spores of cryptogams were tallied in addition to the pollen. Frequency of pollen was calculated based upon the total

pollen sum and percentage of spores was based upon the sum of pollen and spores.

Macrofossils

Samples were taken at 5-cm intervals in Linsley Pond and at 10-cm intervals in Allamuchy Pond (about 50cc and 100 cc, respectively). The samples were soaked overnight in KOH, then washed through 0.5 and 0.1 mm mesh screens. The identifiable plant remains were stored in water and refrigerated prior to AMS ^{14}C dating at Simon Fraser University. Charcoal pieces were counted as numbers of macrofossil fragments retrieved.

AMS-dated macrofossils were combusted with CuO in sealed quartz tubes after normal acid/alkali washes. The samples were then combusted to CO_2 and measured as described by Nelson et al. (1986). Some of the very small samples had relatively large standard deviations due to uncertainty in the background to be subtracted due to contamination during processing (Vogel et al., 1987).

Fish scales and/or vertebra numbers were also retrieved from the macrofossil screening. The scales were placed between microscope slides and viewed with transmitted light at 20X. They were compared to figures in Cockerell (1913), Lagler (1947) and Cooper (1940) and to scales from 85 species of fish representing all 32 families of fishes inhabiting inland waters in the northeastern U.S. The vertebrae were compared to skeletons belonging to Dr K.W. Gobalet, CSU, Bakersfield and skeletons at the New York State Museum, Albany.

RESULTS

The classical pollen stratigraphy for New England is utilized here because the pollen assemblage zones are identical to those first identified over fifty years ago (Deevey, 1939; Leopold, 1956). Some of the New England sites exhibit a basal 'T' tundra pollen zone with high percentages of herbs (see summary in Gaudreau and Webb, 1985). However, unlike Alpine Swamp (Peteet et al., 1990), neither Linsley nor Allamuchy Ponds contain large percentages of basal herb pollen, suggesting that either we did not penetrate to this zone, or that it was not a feature of these sites.

Radiocarbon Dates

The AMS dates provide fine-resolution stratigraphic control of species-specific changes in the cores (Table 1, Figs 2–6). These AMS dates are our best efforts to date pollen assemblage zones which indicate regional vegetational changes. The major changes targeted by the AMS dates are: (1) the first indication of organic deposition 12,590±430 BP in Linsley Pond and 12,260±220 BP in Allamuchy Pond; (2) the beginning of the Younger Dryas cooling 10,740±420 BP in Allamuchy Pond and (3) the end of the Younger Dryas cooling 9920±230 BP in Linsley Pond. Unfortunately, in some samples, a large error bar results from the small sample size.

Percent Organic Carbon

The loss-on-ignition results (Table 2) suggest a gradual

TABLE 1. AMS Radiocarbon dates on identified macrofossils from Linsley Pond, Connecticut and Allamuchy Pond, New Jersey

Lab no.	Sample interval (m)	Size (μg)	^{14}C age (BP)
Linsley Pond, Connecticut			
RIDDL 1137	10.2–10.25 *Pinus strobus* needle	160	9920 ± 230
RIDDL 1138	10.8–10.85 *Betula pap.* cone bract	195	10,440 ± 230
RIDDL 1139	11.9–11.95 *Picea* needle	140	11,500 ± 300
RIDDL 1140	11.95–12 *Picea* needle	115	12,590 ± 430
Allamuchy Pond, New Jersey			
RIDDL 1236	7.8–7.9 *Pinus strobus* needle	200	9230 ± 160
RIDDL 1237	8.5–8.6 *Alnus* seed	78	10,740 ± 420
RIDDL 1238	9.0–9.1 *Picea glauca* needle	205	12,260 ± 220
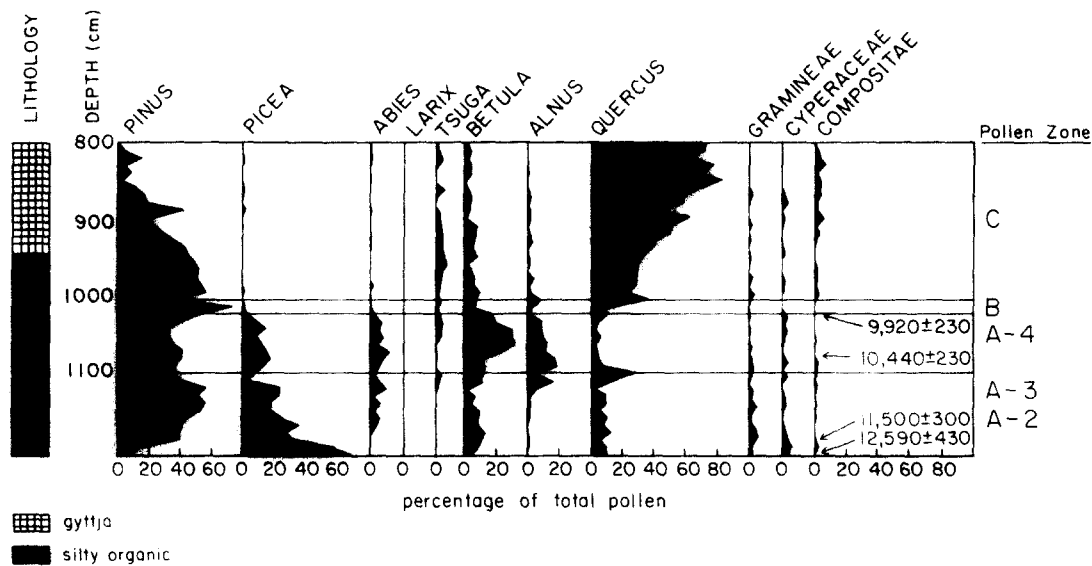
FIG. 2. Pollen percentage diagram of selected types, 8–12 m depth, Linsley Pond, Connecticut.

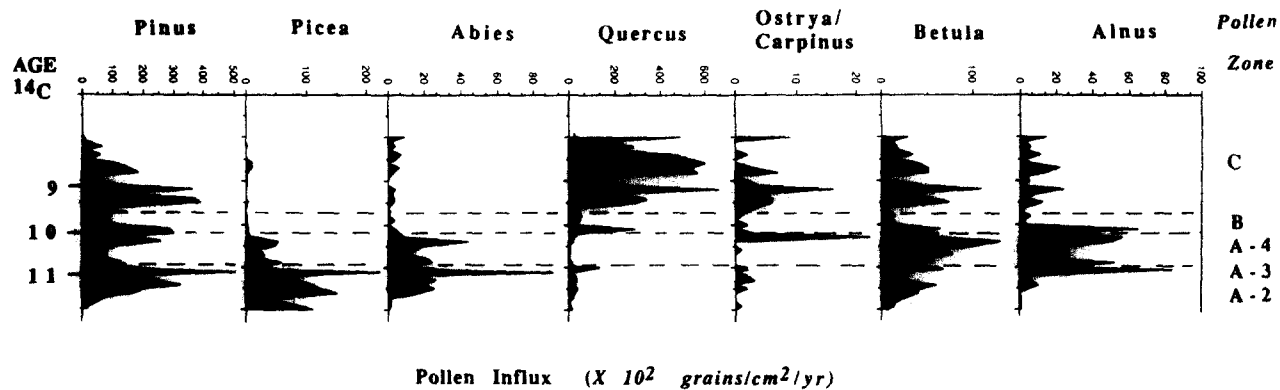Pollen Influx ($X\ 10^2$ *grains/cm²/yr*)

FIG. 3. Pollen influx diagram of selected types, 8–12 m depth, Linsley Pond, Connecticut.
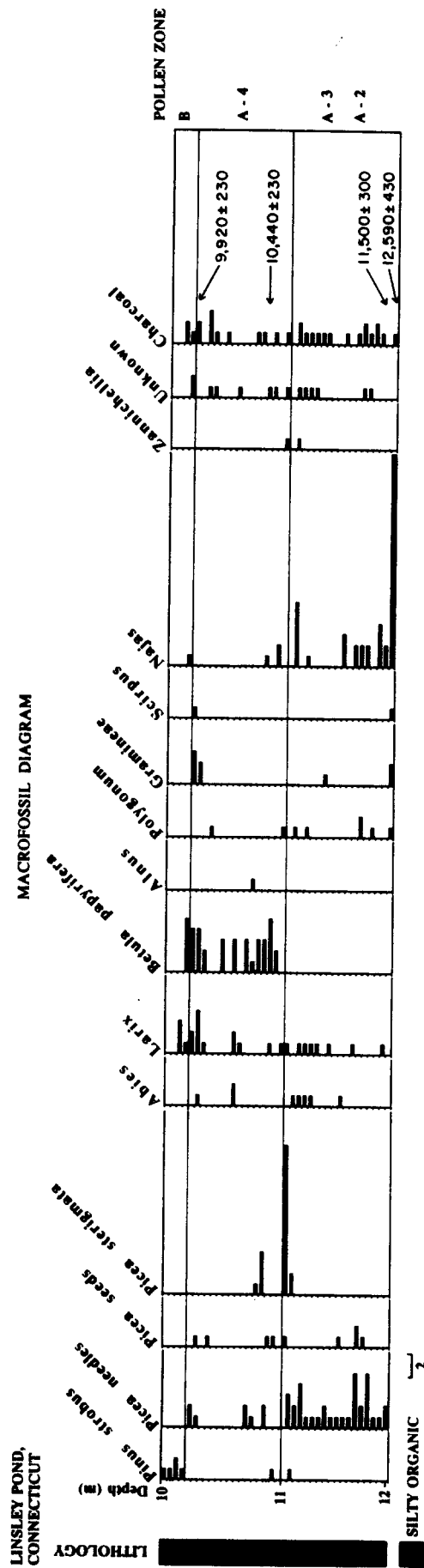
FIG. 4. Macrofossil diagram from 10–12 m depth, Linsley Pond, Connecticut. Samples represent material from 50 cc at 5-cm intervals. *Pinus*, *Abies* and *Larix* macrofossils are needles, *Betula papyrifera* remains includes cone scales and seeds and the remainder denote seeds.
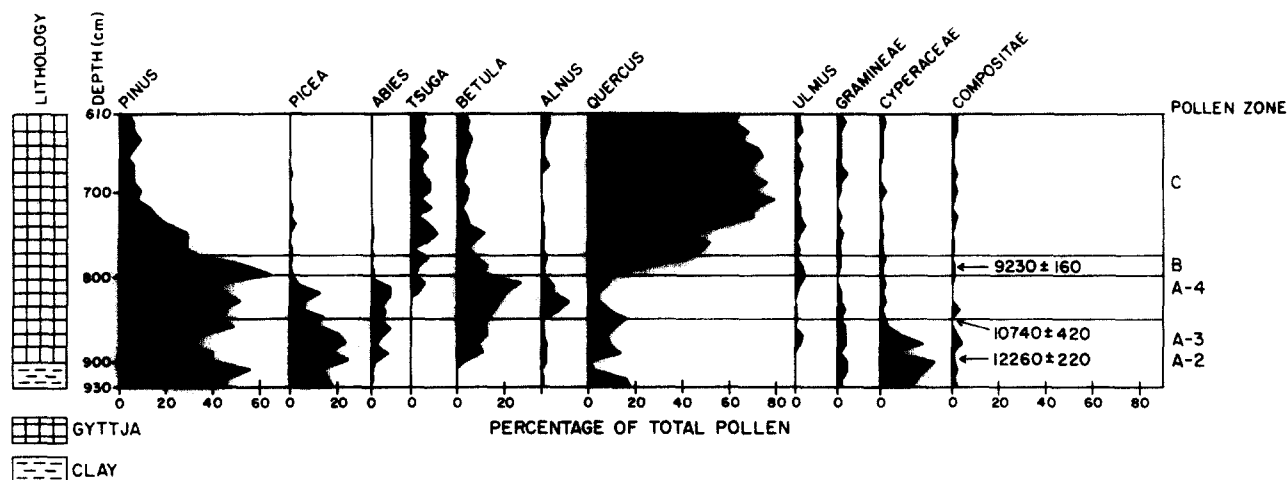
ALLAMUCHY POND,
NEW JERSEY

FIG. 5. Pollen percentage diagram of selected types, 6.1 to 9.3 m depth, Allamuchy Pond, New Jersey.

increase of percent organic carbon over time. In Linsley Pond, the values range from 26.3% in pollen zone A-3 to as high as 60.2% in pollen zone C. These percentages are very close to those in Alpine Swamp, New Jersey (Peteet *et al.*, 1990). In Allamuchy Pond, basal values are as low as 8.7% and increase in zone C to as high as 38.8%. Neither core results indicate a reversal in percent organic carbon with the vegetative change indicative of a cooler climate (zone A-4). However, of interest in Allamuchy Pond is a slight decrease from 31.3% in zone A-3 to 27.3% in overlying zone B.

Linsley Pond (Figs 2–4)

The pollen influx age model for Linsley Pond is based upon the AMS ^{14}C dates in Table 1. Calculation of sedimentation rates is based upon acceptance of the 11.925 m depth of 11,500 BP, the 10.825 m depth as 10,440 BP and the 10.225 m depth as 9920 BP. We used the 11,500 BP basal date on a *Picea* needle for calculation of the basal sedimentation rate because the older needles could have been reworked. Thus the sediment accumulation rates ranges from 0.104 cm/year (11.925 m to 10.825 m) to 0.115 cm/year (10.8 m to 10.225 m) and then to 0.103 cm/year (10.225 to 0 m). Figure 3 illustrates the changes in pollen influx based upon these sediment accumulation rates.

Pollen evidence (Figs 2,3). Five pollen zones are recognized in the core from a depth of 12 to 8 meters.

Zone LP-A-2-3, Picea-Quercus. The pollen assemblage is characterized by high percentages of *Picea* and *Quercus*, with significant percentages of *Betula*. Maximum percentages of *Quercus* rise to greater than 20%. *Alnus* and *Tsuga* percentages rise at the close of A-3, while *Picea* declines. *Pinus* increases upward in the zone, then declines just prior to the transition to A-4. The pollen influx diagram (Fig. 3) suggests that while *Picea* is a dominant pollen type in A-2, *Pinus* and *Quercus* are the major contributors at the close of this zone. In particular, these two genera have greater pollen influx values in portions of this zone than they do in portions of zone C. *Ostrya-Carpinus* influx is also higher in

zone A-3 than in some portions of overlying zones B and C. *Tsuga* begins to increase in this zone.

Zone LP-A-4, Picea-Abies. Increases in percentages of four boreal trees are marked in zone A-4. As pollen percentages of *Picea*, *Abies*, *Larix* (larch), *Betula* and *Alnus* increase, *Quercus* percentages decline. The pollen influx diagram suggests that influx values of all genera decline markedly in this zone compared with A-3, excepting *Betula* and *Alnus*. At the close of this zone, *Ostrya-Carpinus* and *Tsuga* influx values again rise.

Zone LP-B, Pinus. This zone is dominated by *Pinus*, while the boreal conifers, *Betula* and *Alnus* species decline. *Quercus* begins to increase. Pollen influx of *Pinus* and *Quercus* increase in this zone, then drop off.

Zone LP-C, Quercus. *Quercus* makes a dramatic increase in this zone, as *Pinus* declines. *Picea* and *Abies* percentages drop to less than 2%, while *Betula* and *Alnus* also decrease. *Quercus* influx values vary dramatically in this zone, reaching a maximum as well as very low values.

Macrofossil evidence (Fig. 4)

Evidence of the presence of boreal conifers as early as 12,590±430 BP in Connecticut is provided by the occurrence of *Picea* needles. (The needles are thought to be *Picea glauca*, because of the lack of hairs on the *Picea* twigs.) Published keys differentiating between *Picea glauca*, *Picea rubens* and *Picea mariana* needles have been found to be incomplete (see Delcourt, 1979). Maximum numbers of needles occur in the earlier part of this zone, near the basal sediments. These needles, seeds and sterigmata form the major terrestrial macrofossil component of zones A-3 and A-2, along with the needles of *Abies* and *Larix*. *Pinus strobus* needles and *Zanichellia palustris* seeds appear at the close of this zone. The large numbers of *Najas flexilus* seeds may indicate either the shallow water depth or a water quality parameter such as nutrient availability, temperature, or pH. It is interesting to note a similar pattern in large numbers of *Najas flexilis* at Criders Pond, Pa. during the late-glacial (Watts, 1979).
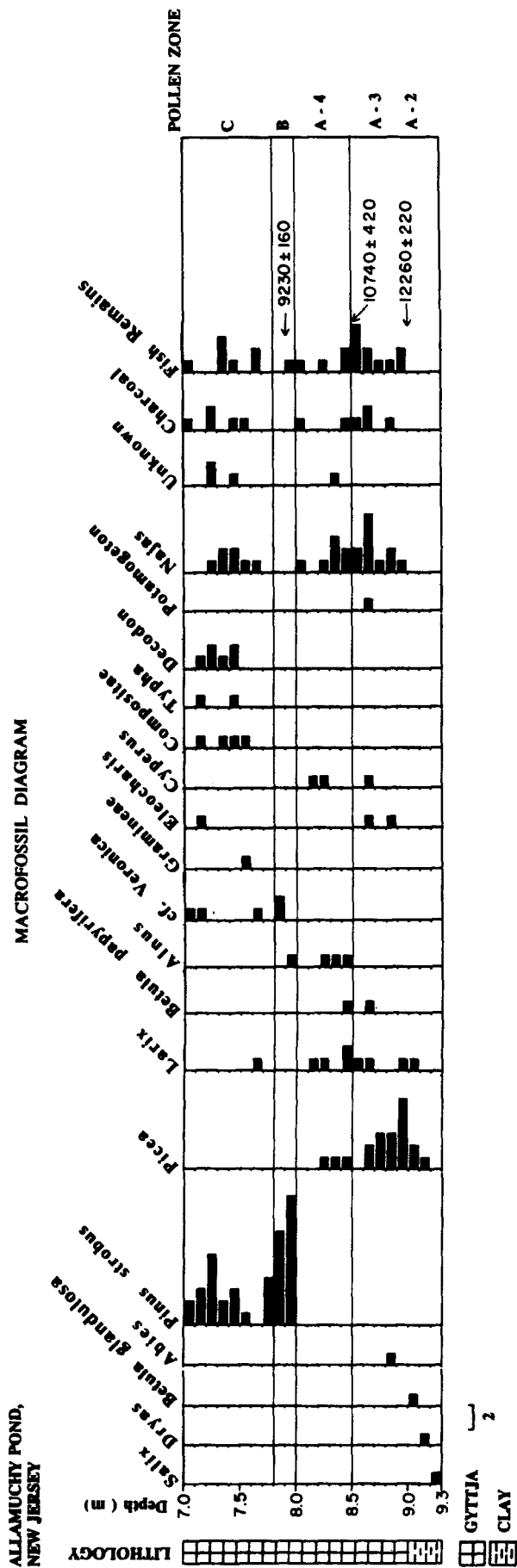
FIG. 6. Macrofossil diagram from 7 to 9.3 m depth, Allamuchy Pond, New Jersey. Conifer remains include needles or needle leaf bases (*Picea*), *Betula glandulosa* cone scale, *Dryas* and *Salix* leaf fragments, and the remaining are seeds unless designated otherwise.

TABLE 2. Loss-on-ignition results for selected samples from Linsley Pond, Connecticut and Allamuchy Pond, New Jersey

Depth (m)	Pollen zone	Loss-on-ignition
Linsley Pond, Connecticut		
9.0	C	60.2
9.5	C	45.5
10.25	A-4	34.6
10.50	A-4	27.8
11.0	A-3	28.4
11.5	A-3	26.3
Allamuchy Pond, New Jersey		
7.0	C	38.9
7.5	C	32.7
8.0	B	27.3
8.2	A-4	31.3
8.8	A-3	16.7
9.0	A-2	8.7

Zone A-4 is distinguished by large numbers of *Betula papyrifera* seeds and cone scales, the presence of the boreal conifers and disappearance of *Pinus strobus* needles along with decreases in *Najas flexilis*.

Zone B marks the return of *Pinus strobus* needles, the disappearance of *Picea*, *Abies* and *Betula papyrifera* macrofossils, along with the return of *Najas flexilis*.

Charcoal fragments are found throughout the core and the number of fragments is slightly higher at the close of zone A-4. However, we do not consider the change significant.

Allamuchy Pond (Figs 5,6)

Pollen evidence (Fig. 5). The same five pollen zones are recognized in the late-glacial to early Holocene record from Allamuchy Pond, New Jersey (Fig. 5). They are as follows: *Zone AL-A2-3, Picea-Quercus.* High percentages of *Picea* and *Quercus* dominate the A-2 and A-3 pollen assemblage zones, with percentages of *Quercus* reaching 20%. *Pinus* ranges from approximately 30–60%, but this probably is long-distance transport. Cyperaceae reach values greater than 20% in this zone as well and *Abies* and *Betula* are also noteworthy components of the A-3 zone. *Ulmus* (not shown) is present in percentages of less than 2%.

Zone AL-A-4, Picea-Abies. The zone is marked by decreases in *Quercus* and *Pinus* and increases in *Abies*, *Betula* and *Alnus*. *Picea* initially declines in this zone, but then also increases. *Tsuga* begins to increase in the upper portion of this zone, just as it does in Linsley Pond and Alpine Swamp (Peteet *et al.*, 1990).

Zone AL-B, Pinus. As the dominants of the previous zone decline, *Pinus* shows a dramatic rise, just as in Linsley Pond. *Quercus* also begins to rise.

Zone AL-C, Quercus. *Pinus* pollen percentages decline, while *Quercus* increases markedly. *Picea*, *Abies* and *Alnus* percentages continue to be low, while *Betula* indicates values close to 10%.

Macrofossil evidence

Botanical (Fig. 6). Basal Zone A-2 has a *Salix* leaf, *Dryas* leaf and *Betula glandulosa* cone scale, along with *Picea* and *Larix* needles. *Picea* needles increase in zone A-3

and an *Abies* needle demonstrates its presence in the Allamuchy region. *Najas flexilis* seeds are most abundant in this zone, just as they are most abundant in basal sediments of Linsley Pond.

Zone A-4 is characterized by *Picea* needles, *Larix* needles, *Betula papyrifera* and *Alnus* seeds and fewer numbers of *Najas flexilis* seeds.

Zone B contains the abrupt appearance of *Pinus strobus* needles and declines in other conifers. *Najas* also is absent in this zone.

Zone C shows the dominance of *Pinus strobus* needles, the resurgence of *Najas flexilis* and some emergents such as *Decodon verticillatus* and *Typha*.

Charcoal fragments are found throughout the samples, but the variability does not appear to be significant.

Fish remains (Figs 7,8)

Seventeen scales or scale fragments were examined. Of these, eleven were ctenoid or ctenoid fragments, three were cycloid, two fragments were probably cycloid and one fragment was not identifiable. Three of the ctenoid scales were regenerated. Six bone or bone fragments were examined. Four fragments were not identifiable, but two vertebra were well-preserved.

Six of the ctenoid scales are from members of the family Centrarchidae (Fig. 7). These scales are characterized by the presence of ctenii in the posterior field, 9–11 primary radii in the anterior field, a central focus and a crenate anterior margin. Scales tend to be quadrate or subquadrate and broader than long, although there is a wide amount of variation in shape among the species and among scales from different parts of the body on an individual fish. The ctenii patch tends to be triangular and does not reach the focus. The columns of ctenii are staggered so that the posterior margin of the scale is uneven in appearance. Apical and subapical ctenii retain their points. These scales are probably from fish in the genus *Lepomis*. The centrarchid scale within the layer 7.9–8 m differs from the others in that it is more circular and has a narrower and longer ctenii patch. This scale may be one of the non lateral scales of a *Lepomis*, but it also matches lateral scales found below the lateral line in fishes in the genera *Micropterus* or *Pomoxis*.

The remaining identifiable ctenoid scales are from *Perca flavescens* (yellow perch). The scales from this fish are distinctive: the anterior margin of the scales are deeply notched at the radii, they possess few primary radii in the anterior field, typically fewer than seven, the focus is closer to the posterior margin, the anterior margin of the ctenii patch is straight and does not touch the focus, only apical ctenii retain points and basal ctenii are quadrate and the rows of ctenii are not staggered. The scale from within interval 8.5–8.6 m is an example of variation within an individual (Fig. 8a). It is also from a yellow perch, even though it is quadrate with only four primary radii. It matches scales from the caudal peduncle area.

Two of the cycloid scales can be identified to a probable family. One (Fig. 8b) is probably from a minnow, family Cyprinidae, although it did not match any scale in the comparative material. North American cyprinids have scales distinguished by radii in the posterior field and a focus close
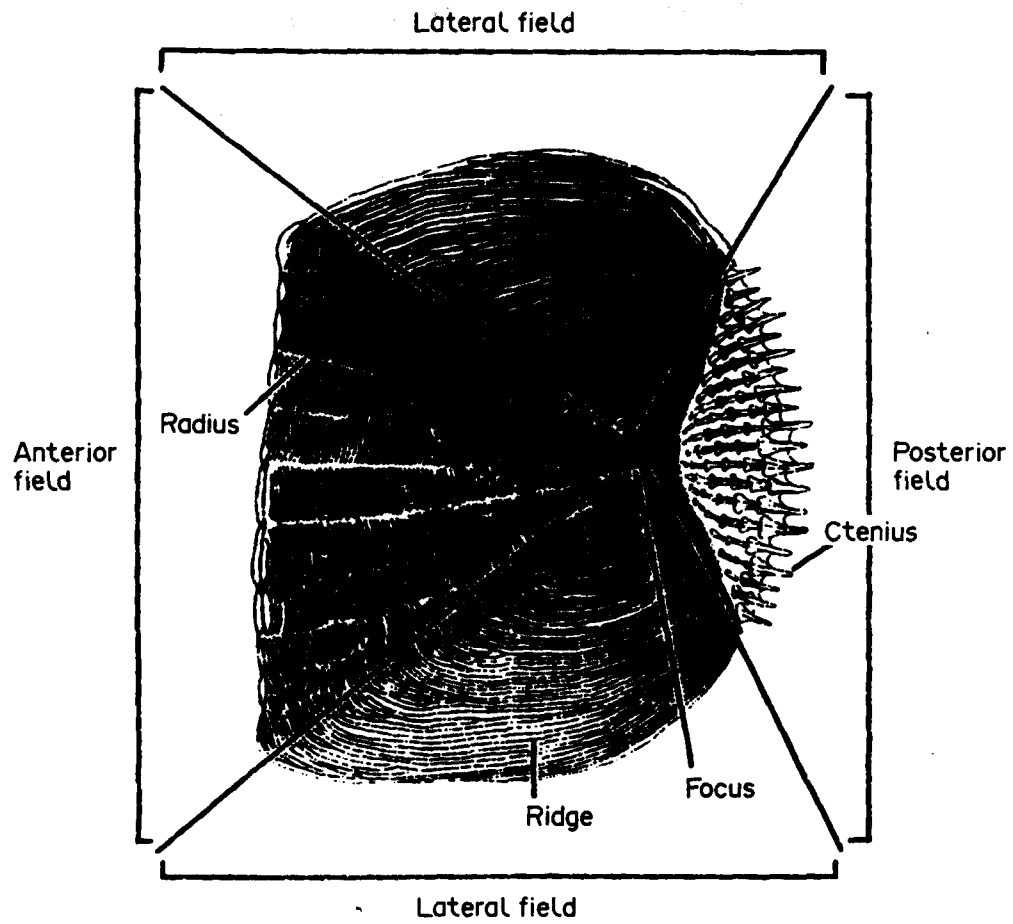
FIG. 7. Ctenoid sunfish scale at depth 7.9–8.0 m, Allamuchy Pond, New Jersey and schematic diagram of descriptive fish scale terms.
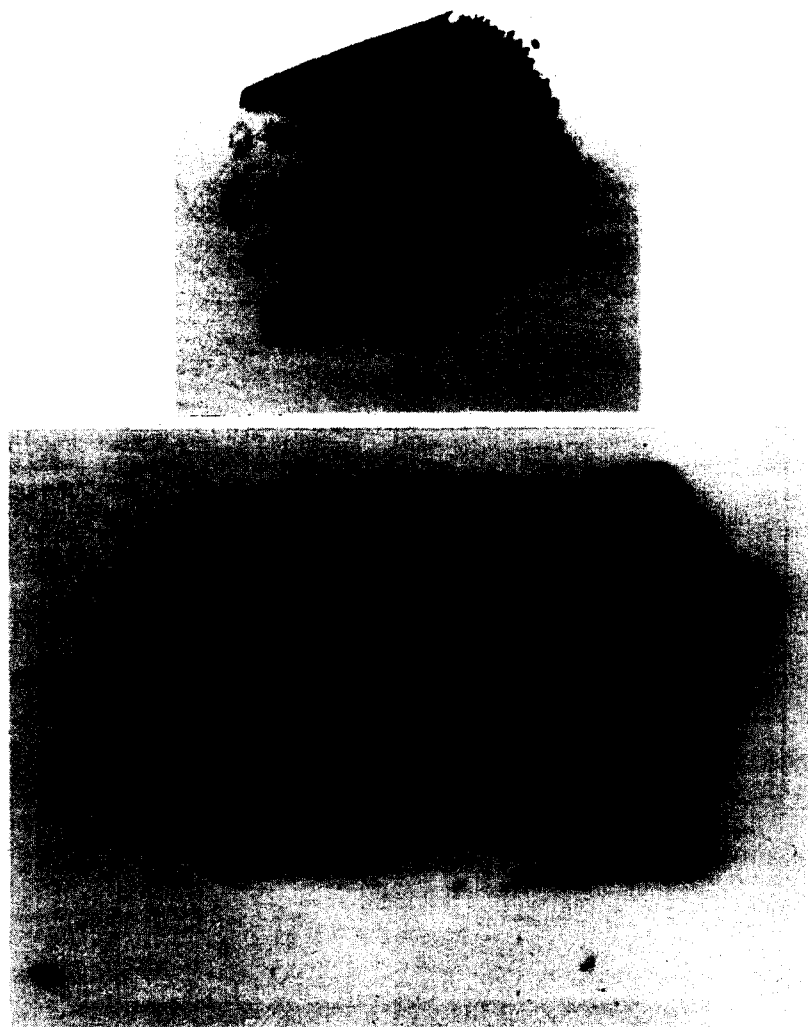
FIG. 8. (a) Ctenoid fish scale, from *Perca flavescens* (yellow perch), at 8.5–8.6 m, Allamuchy Pond, New Jersey (top). (b) Cycloid scale, probably from a minnow, family Cyprinidae, depth 7.35–7.4 m, Allamuchy Pond, New Jersey (bottom).

to the anterior margin. This scale meets these criteria but differs from the comparative material in its width/length ratio and in the presence of parallel radii. A second cycloid scale, from layer 8.8 to 8.9 m is tear-shaped. There are no radii on this scale and ridges encircle an ovoid focus. These scale characteristics are typical of fishes in the family Salmonidae. Other features of this scale are not characteristic of salmonid scales, but, since scales are variable, do not preclude a salmonid identification. The focus sits near the posterior margin of the scale, ridges are more crowded in the posterior field than the anterior field and the tear shape is unusual. However, this scale matches one figured by Cooper (1940) taken from a *Salmo salar*, land-locked Atlantic salmon, in Maine.

The two vertebrae are identified as yellow perch based on the angle of the neural arch and the number and position of struts on the centrum. One is a trunk vertebra, similar in appearance to the posterior-most in the series. The other is the anterior caudal vertebra.

DISCUSSION

Regional Vegetational and Climatic Change

The sequence of pollen assemblage zones is virtually iden-tical for a large region of the northeastern U.S. and southern New England (Watts, 1979; Whitehead, 1979; Gaudreau and Webb, 1985; Peteet, 1987) including southern Connecticut (Deevey, 1939; Leopold, 1956; Davis, 1969; this paper), northern New Jersey (Peteet *et al.*, 1990; this paper), central Mass. (Davis, 1958), the Berkshires, Massachusetts (Whitehead, 1979) and eastern Pennsylvania (Watts, 1979). Cape Cod, Massachusetts, features the same *Picea-Alnus* rise concurrent with a *Quercus* decline (Winkler, 1985) and Hammock River Marsh, Connecticut (Shaw and van de Plassche, 1991) shows a similar pattern. The interpretation of most of these sites has been one of unidirectional vegetational change consistent with continued warming (see Peteet *et al.*, 1990 for full discussion). In contrast to this view, our macrofossil evidence in conjunction with AMS radiocarbon dating at three sites leads us to interpret the A-4 pollen zone (approximately 11–10,000 BP) as a marked *regional* vegetational change consistent with a Younger Dryas cooling. The presence of *Pinus strobus* needles are particularly important as an indicator of warming before and after the Younger Dryas. The modern distribution of *Pinus strobus* (Fig. 9) is temperate in contrast to the boreal distribution of *Picea*, *Abies*, *Larix* and *Betula papyrifera* (Fowells, 1965).
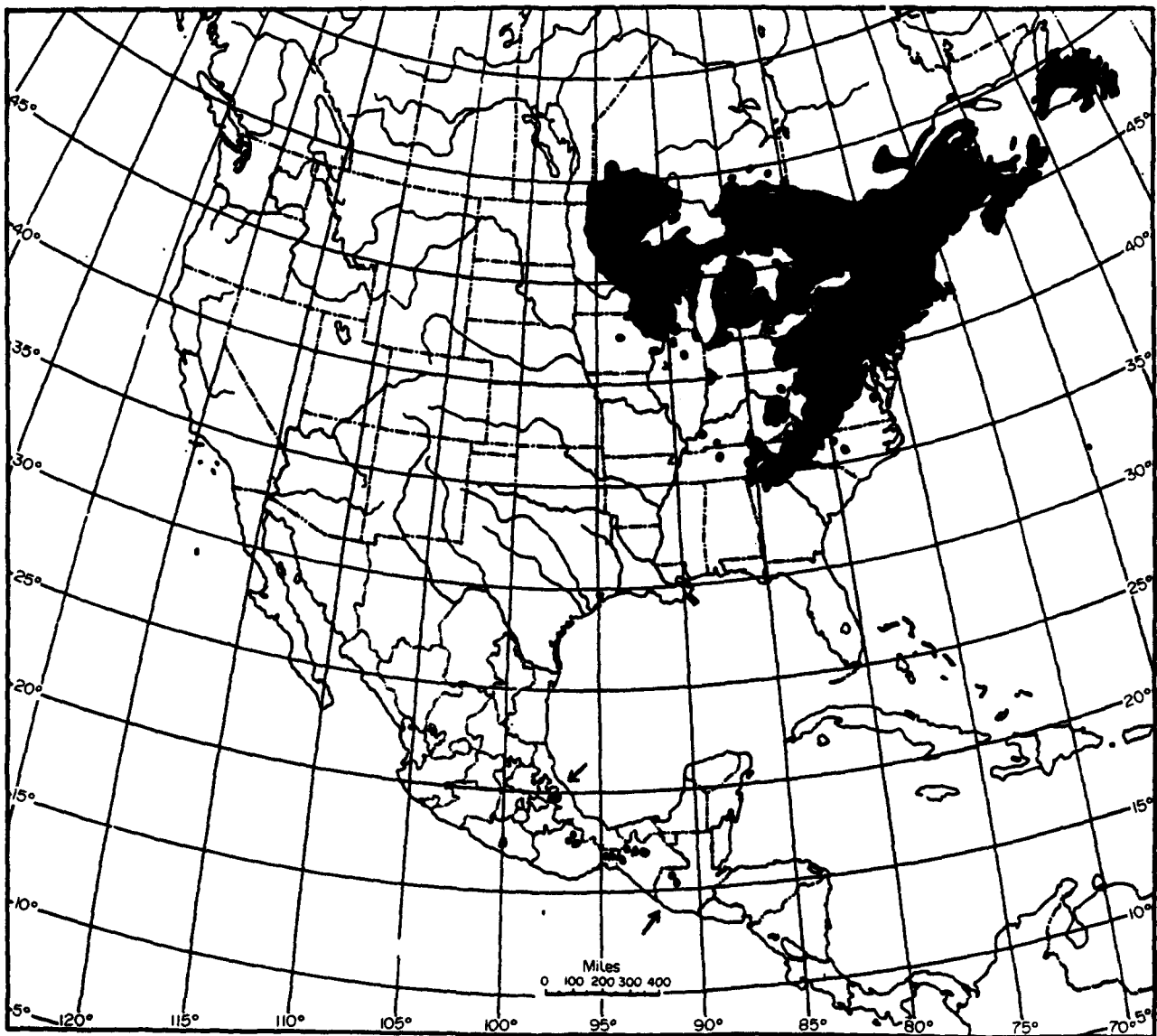
FIG. 9. The modern range of eastern white pine, *Pinus strobus* (after Fowells, 1965).

Zones LP-A-2 and AL-A-2, prior to 12,000 BP. The earliest vegetation at Allamuchy Pond occurred before approximately 12,260, as defined by an AMS-dated *Picea* needle (Fig. 6 and Table 1). At Linsley Pond the first *Picea* needle is 12,590±430 BP (Fig. 4 and Table 1), but the standard deviation is such that deposition could have begun in both basins at approximately the same time. This relatively late organic deposition compared with early estimates of deglaciation (17,000 BP, Borns, 1973; Connally and Sirkin, 1973) and a 15,210 BP date from Crider's Pond, Pennsylvania (Watts, 1979) suggests several alternative explanations. First, it is possible that these relatively old bulk dates are correct and that stagnant ice filled Linsley and Allamuchy Ponds for several thousand years before organic deposition began. Second, we can reject the bulk dates and suggest that ice retreat was actually much later than 17,000 BP locally and the ice retreat was rapidly followed by plant migration to the region. Basal bulk dates from Tannersville, Pennsylvania, (Watts, 1979) are 13,330 BP and Rogers Lake, Connecticut has a basal bulk organic date of 14,240±240 (Stuiver *et al.*, 1963; Davis *et al.*, 1980).

We prefer the second alternative because of the confidence in AMS dates compared with bulk radiocarbon dates and because of the regional AMS pattern for the dates of earliest identifiable macrofossils. For example, Alpine Swamp, New Jersey has a basal *Picea* needle date of 12,290±440, which is very similar to Allamuchy and Linsley Pond. Therefore, we conclude that deglaciation of the area occurred earlier than 12,400 BP, but how much earlier is difficult to ascertain until basal AMS ages are obtained from macrofossils from additional sites.

The initial vegetation at Allamuchy Pond (AL-A-2) was probably a mixture of shrubs, herbs and trees. Although *Pinus* pollen percentages reach values over 40%, it may be long-distance transport because *Pinus* macrofossils were not found here, nor in Alpine Swamp, New Jersey nor in northeastern Pennsylvania (Watts, 1979). The closest documented location of *Pinus banksiana* needles is from Criders Pond, in southeastern Pennsylvania. In contrast, *Picea* reaches values of 20% and was regionally present because *Picea* macrofossils appear in basal Linsley Pond sediments (Fig. 4) as well as in Tannersville and Crider's

Pond, Pennsylvania (Watts, 1979). *Picea* macrofossils are present in Allamuchy Pond sediments along with *Betula glandulosa* and *Dryas integrifolia*, just as they are in Longswamp, Pennsylvania (Watts, 1979). This combination of conifer-dwarf birch is found today in alpine regions of the northeastern U.S. and adjacent Canada (Fernald, 1970). It probably is best defined as a park-tundra environment.

Zone LP-A-3 and AL-A-3, 12,000 to 10,800 BP. While *Pinus, Picea* and *Quercus* are the dominant pollen types in this zone, we do not find evidence of the presence of *Pinus* macrofossils (*Pinus strobus*) near these sites until close to 11,000 BP. The landscape was apparently a mixture of *Picea, Larix* and *Abies*, along with a deciduous component of *Quercus* and significant contributions of *Fraxinus* and *Ostrya-Carpinus* in nearby Alpine Swamp, New Jersey (Peteet *et al.*, 1990) and Rogers Lake, Connecticut (Davis, 1969). We accept the significant percentages of *Quercus* (20%) and relatively high *Quercus* influx values to indicate the presence of this tree regionally, despite the lack of macrofossils. Acorns are rarely ever found in lake sediments and the modern 5% isopoll of *Quercus* lies south of the northern limit of oak trees (Davis and Webb, 1975). The sediments are very organic and total pollen influx at Alpine, New Jersey (Peteet *et al.*, 1990), Rogers Lake, Connecticut (Davis, 1969) and Tannersville Swamp, Pennsylvania (Watts, 1979) are as high in this zone as in mid-Holocene sediments. This view of Zone A-3 as representing a mixed thermophilous deciduous-boreal forest, which we previously hypothesized (Peteet *et al.*, 1990; Peteet, 1992) is reinforced by the identification of temperate *Pinus strobus* needles in Linsley Pond sediments in this pollen zone.

The appearance of *Larix* (pollen and macrofossils) regionally at three sites (Alpine Swamp, New Jersey, Linsley Pond, Connecticut and Allamuchy Pond, New Jersey) as well as at Tannersville, Pennsylvania (pollen) after 13,000 BP is noteworthy. *Larix* is very widely distributed today in the boreal and northern forest regions and grows under extremely varied climatic conditions. Possibly the increasing seasonality of climate was conducive to *Larix* growth, or perhaps *Larix* was simply migrating northward. The late-glacial presence of *Larix* at Rockyhock Bay, North Carolina (Whitehead, 1981) and Browns Pond in Virginia (Kneller and Peteet, 1993) suggests that *Larix* migrated north from the southeastern U.S. The presence of *Abies balsamea* at this same time (pollen and macrofossils) suggests that the climate was mesic and cool.

The close of this zone records the presence of *Pinus strobus* macrofossils in Linsley Pond (Fig. 4) along with high *Pinus* influx. *Pinus strobus* needles also are present at this time in Tannersville, Pennsylvania (Watts, 1979). The presence of this tree at the two sites is strong evidence for a warmer climate, as today its distribution is in the eastern portion of eastern North America (Fig. 9) where July temperatures range from 17 to 22°C (Fowells, 1965). A moisture surplus today occurs in all seasons of its range. The appearance of *Tsuga* at the close of this zone in Linsley Pond also suggests temperate and moist conditions. Although the percentages are low, *Tsuga* pollen is considered to be proportionately represented to basal area (Davis and Goodlett, 1960). The combination of boreal and

thermophilous species suggests a cool and humid climate just prior to 11,000 BP.

Zones LP-A-4 and AL-A-4, 10,800–10,000 BP— Correlative with Younger Dryas. The striking change in pollen percentage in pollen zone A-4 has been noted since the 1930s (Deevey, 1939). The increase in boreal conifers *Picea, Abies and Larix* along with a clear increase in *Alnus* and *Betula* is typical of numerous northeastern U.S. pollen diagrams (Peteet, 1987; Peteet *et al.*, 1990). The *Betula* species is *Betula papyrifera* (Figs 4,6 as indicated by seeds and cone scale bracts), a boreal species as well. We interpret this regional rise in boreal species and decline in thermophilous trees (*Quercus, Pinus strobus*, as well as *Fraxinus, Ostrya-Carpinus* at some sites) to indicate a climatic cooling, possibly as great as 3–4°C (Peteet *et al.*, 1990). The absence of *Pinus strobus* macrofossils in this zone, both at Linsley Pond and at Tannersville, Pennsylvania (Watts, 1979), suggests that the colder climate arrested the migration of *Pinus strobus* northward after ice retreat and either limited pollen production or killed existing stands. Interestingly, at both sites, *Najas flexilis* macrofossils decline during this zone from maximal values in Zone A-3. This may or may not be related to climate change through changes in water quality affected by climate. The decline in total pollen influx at Linsley Pond compared to zones A-3 below it and zone B above it (Fig. 3) suggests less productivity overall, but the same result is not a characteristic of pollen influx in zone A-4 at Alpine Swamp, New Jersey (Peteet *et al.*, 1990). However, pollen influx values may not be reliable indicators of vegetational change, as Batterbee (1991) notes that even different cores from the same lake may give different influx values at the same level.

The timing of this Younger Dryas equivalent is between 10,800 and 10,000 BP, within the classic European Younger Dryas chronozone (Mangerud, 1974). The beginning of this zone is dated at 10,740±420 BP in Allamuchy Pond, New Jersey from one *Alnus* seed. The small size of the sample unfortunately precludes defining the precise timing of the onset of this cooling event. At Linsley Pond, our age model (Fig. 3) derived from available AMS dates (Table 1) places the onset as roughly the same as Allamuchy, which is close to 10,800 BP. The initiation of the Younger Dryas at 10,800 BP is similar to recent European AMS ages for the timing of this interval (Peteet, 1992), both in Ireland (Cwynar and Watts, 1989) and in France (Pons *et al.*, 1987). The termination of the cooling is dated from the first re-appearance of a *Pinus strobus* needle in Linsley Pond at 9,920±230 BP. If we use the sediment accumulation rates from the AMS-dated macrofossils in both cores, we find that this warming took place in 50 to 100 years, which parallels the sudden warming in Greenland noted by Dansgaard *et al.* (1989).

Zone LP-B, AL-B, 10,000–9000 BP

A sharp decline in boreal conifers, *Betula papyrifera* and *Alnus* along with a sudden increase in *Pinus* and a more gradual increase in *Quercus* denotes the warming that took place close to 10,000 BP. The macrofossil evidence for this warming is quite clear, as *Picea* and *Abies* needles and *Betula papyrifera* macrofossils all disappear within a century in this warmer zone. The sudden re-appearance of *Pinus strobus*

indicates the rapid warming that apparently was responsible for the demise of the boreal conifers. No additional *Pinus* species are found in this zone at Allamuchy Pond, Linsley Pond, or Alpine Swamp, New Jersey. This suggests that the 'B' pine pollen zone represents a time of major *Pinus strobus* dominance in the northeastern U.S. However, the documentation of *Larix* needles in zones B (Linsley) and C (Allamuchy) indicate that it was able to remain at these wetland sites despite the changes in climate. *Larix* is often found today in wetlands of this northeastern U.S. region.

The duration of the classical 'B' Pine pollen zone is difficult to determine and more detailed analysis of this zone and the beginning of the 'C' zone is needed. However, a date of 9230±160 BP on a *Pinus strobus* needle in the B zone from Allamuchy Pond suggests that it lasted at least 600 and possibly a thousand years.

Comparison with extra-regional palynological sites

In southwestern New York, the palynological stratigraphy is not as striking a pattern as in more coastal sites. Allenberg Bog shows a *Quercus-Fraxinus* oscillation with *Picea*, but this oscillation appears to begin earlier and because it is not clearly matched in pollen influx, Miller (1973) interprets it simply as an increase of *Picea-Pinus* forests on the landscape. However, he accepts the presence of *Quercus*, *Fraxinus* and *Ostrya/Carpinus* in the 'A' pollen zone as possibly a regional signal, suggesting that these thermophilous trees occupied sites within tens of miles from the basins (Miller, 1973). A slight oscillation in *Quercus* pollen influx may record a cooling, but lack of chronological control precludes correlation with southern New England sites. It is interesting to note that recent macrofossil analysis shows that *Pinus banksiana* was in western New York at the Hiscock site 11,200 BP (Miller, 1990). Thus it was a possible source for the windblown pine pollen in the coastal sites.

Most palynological sites in the high mountains of the Adirondacks, New York were not deglaciated as early as the sites in New Jersey, Connecticut and southern New York (Whitehead and Jackson, 1990). However, a bulk date from Upper Wallface Pond, New York suggests that deglaciation took place there around 12,300 BP (Whitehead and Jackson, 1990). The sampling resolution and poor chronological control makes correlation with the southern New England sites marginal, but Heart Lake, Adirondacks, New York, does show a drop in thermophilous species (*Carya, Fraxinus, Ulmus, Ostrya-Carpinus*) concurrent with a *Picea* increase at 10,475 BP (Whitehead and Jackson, 1990). The *Picea* increase is immediately followed by an increase in *Alnus* and *Betula papyrifera*, which may indicate a successional advance of light-demanding species with the decline of *Picea*.

To the east, in the White Mountains of New Hampshire, Deer Lake Bog and Lake of the Clouds show a pattern similar to the general pattern of 11 to 10,000 BP, in which the thermophilous rise (*Quercus* at 10%) is suddenly followed by a *Quercus* decrease concurrent with a rise in *Picea, Betula* and *Alnus* and a drop in total pollen influx (Spear, 1989). *Picea* and *Alnus* then decrease with the subsequent rise of *Quercus, Pinus* and *Betula*. Although the deposition rates are low in the late-glacial sediment of these cores (less than 1 m

per five thousand years versus 0.75 m per thousand years in southern New England), the palynological oscillation suggests that this thermophilous-boreal reversal is consistent from northern to southern New England. The large *Alnus* rise between 11,000 and 10,000 BP may indicate disturbance from severe winters, as suggested for sites to the south (Peteet *et al.*, 1990).

Although a number of sites in northern New England contain a late-glacial sequence back to at least 12,000 BP, many of these are unpublished (Davis and Jacobson, 1985). The available data have been interpreted to indicate progressive late-glacial and early Holocene warming (Davis and Jacobson, 1985). While some cores apparently do not have the resolution to record the late-glacial in detail, Gould Pond, Maine (Jacobson *et al.*, 1987) shows a clear *Picea-Alnus* rise concurrent with a *Quercus* decline between 11,000 and 10,000 BP, suggesting an extension of the regional pattern. Further research is needed to establish the timing of this pattern securely.

Sites in Atlantic Canada have recorded the Allerod/Younger Dryas through both lithological and palynological changes (Mott *et al.*, 1986; Mayle *et al.*, *in press*) as well as paleotemperature reconstructions of lakes based upon chironomid larvae (Levesque *et al.*, 1993). The pattern of vegetational change with the onset of the Younger Dryas is variable within Atlantic Canada and ranges from a change from woodland to shrub-tundra or from shrub-tundra to herb-tundra (Levesque *et al.*, 1993). However, the rise in *Alnus* is a common signal to these sites as well as those in northern and southern New England (Mayle *et al.*, *in press*).

In summary, the northern New England and adjacent Atlantic Canadian sites do show a late-glacial oscillation that often includes an increase in *Picea* and *Alnus* at the Younger Dryas chronozone, 11–10,000 BP. We interpret this vegetational change spanning 5 degrees of latitude as indicative of a major climatic cooling that took place in response to the cooling of the North Atlantic (Ruddiman and McIntyre, 1981; Broecker *et al.*, 1985) and changes in atmospheric circulation as evidenced from ice cores (Taylor *et al.*, 1993; Alley *et al.*, 1993).

Several questions concerning late-glacial climate in eastern North America indicate the importance of additional study, with particular emphasis on fine resolution analysis. Does the Younger Dryas interval include changes *within* this zone that can be interpreted climatically? Is the radiocarbon plateau (Amman and Lotter, 1989) visible in U.S. late-glacial records? Did the migration of *Pinus strobus* originate from regions to the south or from the western Great Lakes region? How long did the 'B' *Pinus strobus* zone last?

Allamuchy pond fish remains

Allamuchy Pond fish remains encompass a mix of scales that is not unexpected based on previous reports. Ctenoid scales are more numerous than cycloid since cycloid scales are less bony and will tend to decompose more rapidly (Hopkirk, 1988).

No recent reports document the fish assemblage in Allamuchy Pond today, but the assemblage present during the late-glacial and early Holocene is not unlike the assemblage found in ponds throughout the northeast today. It

consisted of sunfish, minnow, trout and yellow perch. Other fishes are often present in modern ponds, but they are typically soft-rayed fishes like *Notemigonus crysoleucas* (golden shiners) and *Catostomus* sp.(suckers) or fishes without scales like *Ameiurus* sp (bullheads) or *Cottus* sp. (sculpins). It is, perhaps, not surprising then that the remains of these other fishes were not collected in the core.

However, several questions concerning the fish remain. The one ctenoid scale that matches the *Micropterus* (black bass) or *Pomoxis* (crappie) scale is puzzling since these fishes are not considered native to the area. The minnow scale appears more robust and thicker than any minnow scale from the comparative collection. Parallel radii are also unusual on minnow scales, although they were observed on a few scales in the reference material.

The most interesting scale is that of the salmonid, identified as a scale from *Salmo salar*, the Atlantic salmon. Atlantic salmon are an anadromous fish that make annual spawning migrations into coastal rivers and streams in North America and Europe. Some native land-locked populations also exist in Canada and New England. Historically, Atlantic salmon have not entered streams south of the Housatonic River system in Connecticut (Bigelow and Schroeder, 1953), although early explorers reported their presence in the Hudson River (see Smith, 1985). The presence of an Atlantic salmon in Allamuchy Pond in the Delaware River system is an important find and indicates that this species migrated north with the glacial retreat. Additional samples may aid in interpreting these data.

CONCLUSIONS

(1) Initial organic deposition, as evidenced by AMS ages on terrestrial macrofossils from these three lakes, began about 12,400 BP. This age, which roughly coincides with the Bölling warming in Europe (Watts, 1980) and Greenland ice cores (Johnsen *et al.*, 1992; Taylor *et al.*, 1993; Alley *et al.*, 1993) shows that the timing of significant climatic change as evidenced by major vegetational change, is similar across the North Atlantic. Thus it appears that a major climatic warming abruptly took place throughout at least half the Northern Hemisphere at this time, affecting vegetation significantly. This major warming was apparently caused or dramatically enhanced by increased North Atlantic Deep Water Production (Broecker *et al.*, 1985). However, the timing of the *initial* warming responsible for ice retreat allowing these lakes to form, is derived from sites to the south and appears to begin as early as 17,000 BP (Kneller and Peteet, 1993).

(2) Remains of *Picea* are found at all three sites in the basal sediments. *Larix* and *Abies* were also present and at the close of the late-glacial warm (Alleröd) interval, *Pinus strobus* macrofossils appear and *Quercus* pollen percentages and influx increase, suggesting further warming. A change in the abundance of the aquatic *Najas flexilis* possibly suggests a change in the nutrients, water depth, or water temperature. Fish remains occur throughout the core, but do not indicate species oscillations which are indicative of climate change. However, presence of Atlantic salmon in the sample is indicative of a general change in species composition that has occurred in the intervening 12,000 years.

(3) The Younger Dryas reversal appears in the three sites as the classical southern New England A-4 pollen assemblage zone in which *Picea, Abies, Larix, Betula* and *Alnus* increase at the expense of *Quercus* and sometimes *Fraxinus, Ostrya-Carpinus* and *Tsuga*. From macrofossil evidence, we know the *Betula* species is *Betula papyrifera*, a boreal species. Macrofossil evidence of *Pinus strobus* at Linsley Pond indicates a cool, humid climate prior to the more severe Younger Dryas cooling, suggesting a change in annual temperature of 3–4°C. (Peteet *et al.*, 1990). The timing of the Younger Dryas is roughly 10,800 to 10,000 BP, as evidenced by AMS ^{14}C dates. The best constraint on the close of the A-4 pollen zone, which correlates with the Younger Dryas chronozone (Mangerud, 1974), is the first re-appearance of a *Pinus strobus* needle in Linsley Pond AMS-dated at 9920±230 BP. This climatic warming occurred in approximately 50–100 years, based on sediment accumulation rates.

(4) The classical southern New England *Pinus* pollen assemblage zone B, approximately 10–9000 BP, is clearly marked by the sudden decline of boreal species and the resurgence of *Pinus*. The three lake macrofossil records indicate the presence of *Pinus strobus* needles in this zone, which in conjuction with other regional records suggests that this tree dominated the forest and the climate was much warmer than the previous millenium. It is difficult to determine the degree of warmth because this species extends from Atlantic Canada south to Georgia and increased along with *Quercus*, another thermophilous species.

(5) To our knowledge, this is the first continuous fish remains record for the eastern United States. The sequence of scales includes sunfish, minnow, trout and yellow perch. Too few remains were collected to assess the stability of the fish assemblage within the Bölling/Alleröd-Younger Dryas. Today, sunfish, minnows, trout and yellow perch are found in a variety of habitats and appear tolerant of a wide range of environmental variables associated with climate, such as temperature. One fish that has not persisted in the drainage in which Allamuchy Pond occurs is the Atlantic salmon. The loss of this fish from the assemblage may be related to climatic change.

ACKNOWLEDGEMENTS

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